Chapter 4 – Energy Resource Options

Contents

4 Energy Resource Options 61

4.1 Introduction 61

4.2 Options Identified but Not Further Evaluated 62

4.3 Options Included in IRP Evaluation 63

4.3.1 Fossil-Fueled Generation 63

4.3.2 Nuclear Generation 67

4.3.3 Renewable Generation 68

4.3.4 Energy Storage 74

4.3.5 Energy Efficiency and Demand Response 75

4 Energy Resource Options

4.1 Introduction

At the heart of its ability to provide low cost, reliable, clean electric power to the consumer are TVA's power generation and transmission systems. For TVA to continue providing low cost, reliable and clean electric power, it will need additional generating capacity as well as an increase in demand-side resources as discussed in Chapter 3, Need for Power.

In EV2020, TVA evaluated hundreds of different resource options and summarized its evaluations in the final combined IRP and EIS. To update those evaluations in this IRP, TVA has reviewed resource options that are currently or are expected to be commercially available by 2029. The purpose of this chapter is to describe these energy resource options, which of these options were focused on, and why.

The following criteria were applied to determine what options should be considered as viable in the IRP:

- The resource options must utilize a developed and proven technology, or one that has reasonable prospects of becoming commercially available before 2029.
- The resource options must be available to TVA, either within the TVA region or importable through market purchases.

- The resource options must be reasonably economical and contribute to the reduction of emissions of air pollutants, including greenhouse gases from the TVA power supply portfolio, in alignment with overall TVA objectives.
- The resource options should not be excessively risky or speculative.

TVA's future portfolio of generating assets must consist of a broad cross section of different technologies to support varying power demand. These technologies can be characterized by how often they are utilized for producing power (sometimes referred to as where they fit in the "duty cycle") and consist of peaking assets which respond quickly when power demand is very high for short periods of time; intermediate assets that respond reasonably quickly and fill the next level of power demand for longer periods; and finally, base load assets that meet a fairly constant level of power demand by operating for extended periods of time. In addition to these assets, storage units, which are used to store energy during off-peak periods for use during peak periods, will also be employed. Finally, TVA's portfolio is expected to include power purchases through both short- and long-term contracts, as well as demand-side options like energy efficiency and demand response programs (EEDR), where cost effective and reliable.

4.2 Options Identified but Not Further Evaluated

During the scoping process, TVA identified a broad range of resource options. The criteria listed in Section 4.1 were applied to these options to narrow them down to a more manageable portfolio based on the aforementioned criteria.

In general, there were four primary reasons these resource options were not considered for further analysis as separate options in the IRP:

1. The technology was still in very early stages in terms of maturity, either in the research phase or under development but not widely available during the IRP planning period.
2. The resource option was either previously considered by TVA and found to be uneconomic or not technically feasible.
3. The resource option is considered part of what private developers or individuals could elect to do as part of their participation in EEDR programs or their development of renewable resource purchase options for TVA consideration, but is not a resource option TVA would implement on its own.
4. The resource option is already part of TVA's resource plan.

4.3 Options Included in IRP Evaluation

This section identifies and describes the set of resource options that TVA considered in this IRP evaluation. Existing assets in TVA's current generation portfolio are described including owned facilities and power purchases. Options for new generation include owned assets and power purchases, and repowering of current assets is also considered. The main areas are fossil-fuel generation, nuclear generation, renewable generation, energy storage, and energy efficiency and demand response (EEDR).

Power purchases refer to the procurement of energy and/or capacity from other suppliers for use on the TVA system in lieu of TVA constructing and operating its own resources. TVA is currently party to numerous short- and long-term power purchase agreements and has included PPA options in its IRP evaluation. For all PPAs, TVA assumes the supplier will either interconnect with TVA transmission or obtain a transmission path to TVA, if outside the TVA region.

Repowering electrical generating plants is the process by which utilities update, change the fuel source or change the technology of existing plants to realize gains in efficiency or output not possible at the time the plant was constructed. TVA has included approved repowering projects in its forecast for existing resources and included other as-yet-unapproved repowering options in its IRP evaluation.

4.3.1 Fossil-Fueled Generation

4.3.1.1 Coal

Coal – Existing Generation

TVA currently operates 59 coal-fired generating units at 11 generating plants with a total capacity of 14,500 MW (net dependable). While some strategies assume the continued operation of all of these assets, others assume placing varying amounts of coal-fired generating capacity into long-term layup status for the foreseeable future. The goal of a long-term layup is the preservation of the asset so that it could be re-integrated into TVA's generating portfolio in the future if power system conditions were to warrant it.

In addition to its own coal-fired assets, TVA also has access to the output from a coal-fired power plant (of approximately 430 MW) through a long-term purchased power agreement.

Coal – New Generation

TVA has included supercritical pulverized coal (SCPC) plants with carbon capture and storage (CCS) technology, as well as integrated gasification combined cycle (IGCC) plants with CCS technology as resource options in its IRP evaluation. Pulverized coal, SCPC and IGCC options without CCS technology were not considered in the IRP evaluation due to their higher CO_2 emissions.

In a pulverized coal (PC) plant, finely ground (pulverized) coal is injected into the boiler with sufficient air to ensure combustion. In the boiler, heat is absorbed from the resulting hot gas to boil water and make steam, which then turns a steam turbine to generate electricity. Nitrous oxides (NO_x), sulfur dioxide (SO_2), and particulate matter are removed from the gas after it leaves the boiler and before it is released into the atmosphere. A supercritical PC (SCPC) plant is an advanced version of a PC plant. While it is technically similar to the PC plant, the exception is that the SCPC's supercritical boiler operates at supercritical steam pressures of greater than 3,200 pounds per square inch. The higher-pressure steam cycle provides greater efficiency, meaning more electricity per ton of coal burned in the process. Specifically, supercritical units have a thermal efficiency that is about two percentage points better than conventional sub-critical units as well as 5% lower emissions of SO_2, NO_X, mercury, and carbon dioxide (CO_2). CO_2 emissions are a function of the efficiency of the plant in converting heat from the coal burned into electricity, with the lowest CO_2 emissions from the plants with highest efficiency.

Two configurations of new SCPC plants are considered in the IRP evaluation:

1. Single-unit 800-MW SCPC plant with CCS
2. Two-unit 1600-MW SCPC plant with CCS

IGCC plants differ significantly from PC plants. They generate electricity in the same manner as natural gas-fired combined cycle plants (see Section 4.3.1.2), except that a relatively clean, burnable gas produced from coal is burned instead of natural gas.

The basic gasification process involves crushing the coal and partially oxidizing (i.e., burning) the carbon in the coal. Partial oxidation converts the coal into a gaseous fuel composed primarily of combustible hydrogen and carbon monoxide. The gas can be piped directly into a gas turbine to generate electricity. The exhaust from the gas turbine is ducted into a heat recovery steam generator to produce steam for a conventional steam turbine generator. The combined cycle features of the IGCC plant provide a higher efficiency than either a simple cycle combustion turbine plant or a pulverized coal-fired plant. Higher auxiliary power consumption, primarily by the air separation unit, reduces efficiency below a natural gas-fired combined cycle plant. Sulfur dioxide emissions are quite low due to the high sulfur recovery from the synthesis gas in the sulfur removal process. The low nitrogen content in the synthesis gas, and the use of low NO_x combustion technology in the combustion turbine, limits NO_x emissions to very low levels, as well.

As a means to reduce greenhouse gas emissions, CCS technologies—when they are developed—could be integrated into new fossil-fired power plants including PC, SCPC and IGCC units. A CCS system installed on a PC or SCPC power plant would capture post-combustion gases before they are vented to the atmosphere. The vented gases are passed through a scrubbing system where the CO_2 is absorbed, compressed and transported to storage. A CCS system installed on an IGCC plant would be located before the power generation step, or pre-combustion (PNNL 2009). The CO_2 is absorbed in a similar manner as in the PC plant. A consequence of using CCS technology is higher capital investment and operating costs, whether using PC, SCPC or IGCC technology.

4.3.1.2 Natural Gas

Natural Gas – Existing Generation

Composed mainly of methane, natural gas is a source of fossil energy that results in lower greenhouse gas emissions and most other emissions than power produced by coal-fired plants. TVA has 87 combustion turbines (CT) at nine power plants, with a combined generating capacity of approximately 6,000 MW. TVA also has the capacity to generate up to 890 MW from its Southhaven combined cycle plant and is in the process of completing construction of the 880 MW John Sevier combined cycle plant. The refurbishment of the gas-fired Gleason plant, consisting of three gas-fired combustion turbines, is evaluated as a resource option in the IRP, which increases the available capacity from 360-530 MW. The IRP study also includes the 540 MW Lagoon Creek Combined Cycle Facility, which came online in late summer 2010.

Power purchases from natural gas-fired units owned by independent power producers are also part of the current resource portfolio. TVA is currently party to a long-term lease of a 900 MW combustion turbine plant and has purchased power agreements of over 1,000 MW related to natural gas-fired combined cycle plants.

Natural Gas – New Generation

The IRP evaluation includes both simple and combined cycle natural gas fueled options. In a simple cycle unit, natural gas is used in the fueling of combustion turbines, where it is combusted with air at high pressure and temperature, then expanded to drive a shaft through which shaft work is used to power an electric generator. The major emissions from combustion turbines fired with natural gas are nitrogen oxides (NO_x) and CO_2. To reduce NO_x emissions, dry, low NO_x burners are typically used. Natural gas contains negligible amounts of sulfur, so sulfur dioxide (SO_2) emissions are essentially zero. The higher hydrogen content of the natural gas fuel relative to coal creates lower carbon dioxide (CO_2) emissions on an energy input basis than the emissions from coal-fired power plants.

Several features of simple cycle combustion turbines (CTs), including their relatively low capital cost, short construction times, low emissions and rapid start-up times, make them attractive for generating peaking power during short periods of high demand. Because of their relatively high fuel costs and relatively low efficiency, they are not as well suited for providing intermediate and base load power as combined cycle CTs, pulverized coal plants and nuclear plants. Up to approximately 6000 MW of self-built, TVA-owned simple cycle CT technology for peaking use is evaluated as a resource option.

Combined cycle plants direct the exhaust gas from the combustion turbine of the simple cycle to a heat recovery steam generator, which feeds an additional steam turbine and electric generator. NO_x emissions from the combined cycle combustion turbine can be controlled, and sulfur dioxide emissions from the natural gas fuel are essentially zero. The high efficiency and natural gas fuel combine to produce relatively low CO_2 emissions.

Features of the combined cycle CT option, including its high efficiency, moderate capital cost, relatively high fuel cost, low emissions and short construction time, make this technology a candidate for intermediate capacity additions. Intermediate capacity is expected to operate as required to follow variations in system load. Depending on system load, intermediate capacity may shutdown at night and during weekends, when demand for power is relatively low. Resource options evaluated in the IRP include procurement of power from existing merchant combined cycle plants along with self-built TVA or customer-owned combined cycle plants of up to 1730 MW without specific site locations.

4.3.1.3 Petroleum Fuels

Currently, TVA contracts for a number of diesel fuel generated power purchases, totaling 120 MW, that are expected to be phased out by 2029. There are no diesel fuels or other petroleum based resource options as a primary fuel source under consideration in the IRP because of emissions from these types of facilities.

4.3.2 Nuclear Generation

Nuclear – Existing Generation

The capacity of TVA's existing nuclear units is 6,900 MW, which includes three reactors at TVA's Browns Ferry Nuclear Plant, two at Sequoyah Nuclear Plant, and one at Watts Bar Nuclear Plant. On August 1, 2007, the TVA Board approved the completion of the 1150 MW Unit 2 at the Watts Bar Nuclear Plant. The project is included as a current resource in TVA's generating portfolio and is scheduled for completion in the fall of 2012.

Moreover, the NRC has approved power uprates for TVA's Browns Ferry, Sequoyah and Watts Bar plants since 1998, and additional uprates for its Browns Ferry units are incorporated into the forecast of the capacity of existing resources.

Nuclear – New Generation

TVA has included Bellefonte Units 1 and 2 as well as Units 3 and 4 in the IRP evaluation. In addition to the four Bellefonte units, a non-site specific option based on the Advanced Passive 1000 reactor is also included in the IRP.

Located at the Bellefonte site in northeast Alabama, Bellefonte Units 1 and 2 are the two partially completed Babcock and Wilcox (B&W) pressurized light water reactors with a capacity of 1,260 MW each. Preliminary construction on the Bellefonte site was started in 1974, but construction activities were deferred, with plant systems being maintained to allow reactivation on a schedule to meet future power requirements. On March 9, 2009, the NRC issued an order reinstating the construction permits for Bellefonte Units 1 and 2. Reinstatement of the construction permits, however, does not mean TVA can re-commence construction of these units. Before construction activities can resume, further action by the NRC is required, the contentions that have been filed concerning the resumption of construction must be resolved, and the TVA Board must approve the project. On August 20, 2010, the TVA Board approved funding for additional engineering, design and other activities at Unit 1 to maintain its feasibility as a resource option in the 2018-2019 time period. It is anticipated that the Board will be asked to approve re-commencement of the construction at Unit 1 depending on the outcome of this IRP in spring 2011. The completion of the first unit at Bellefonte, if approved, is expected to take eight years. The second unit at Bellefonte should take six years to complete, assuming the first unit is finished. The lifetime of the units is expected to be at least 40 years. A separate Bellefonte supplemental environmental impact study (SEIS) under NEPA was completed on locating one nuclear unit on the Bellefonte site.

In October 2007, TVA submitted a Combined Construction and Operating License Application to the NRC for two new Westinghouse Electric Co. designed Advanced Passive 1000 reactors. These reactors are to be located at the Bellefonte site and designated as Bellefonte Units 3 and 4 to demonstrate the feasibility of NRC's then new combined construction and operation licensing process. TVA's application was being supported, in part, by NuStart, an industry consortium comprised of 10 utilities and two reactor vendors whose purpose is to satisfactorily demonstrate the new NRC licensing process for new nuclear plants. The Bellefonte Combined Construction and Operating License Application is one of several Advanced Passive 1000 Westinghouse standardized plant applications, and other applicants have announced construction schedules that call for their license reviews to be completed prior to Bellefonte's. As a result, NuStart, with TVA's agreement, is transitioning its reference plant to the Combined Construction and Operating License Application of another utility. TVA has not proposed to add these units to the Bellefonte site, but TVA plans to continue to support the review of the Bellefonte application and does not expect this transition, by itself, to impact the issuance of a license for Bellefonte Units 3 and 4. Contentions have been filed with respect to the Bellefonte Combined Construction and Operating License Application.

4.3.3 Renewable Generation

TVA presently provides renewable energy from TVA facilities and acquired by PPAs generated by hydroelectric, solar, wind and biomass-fueled facilities. As described below, renewable energy from these sources is considered in the IRP. Geothermal energy is not considered because it is not available in or near the TVA region.

4.3.3.1 Hydroelectric

Hydroelectric – Existing Generation

TVA operates conventional hydroelectric generating facilities at 29 of its dams. These facilities have the capacity to generate 3,538 MW of electricity. TVA is also systematically updating aging turbines and other equipment in its powerhouses. The major benefit of this hydro modernization effort is the generation of more power from the same amount of water. Modernization projects that already are approved are included in the forecast of TVA's current hydro resources. TVA also has purchases output from approximately 690 MW of hydroelectric facilities located in the Tennessee Valley, but owned and operated by other parties.

Hydroelectric generation is often considered to be renewable because the fuel, water, is essentially infinite and its availability is determined by the watershed's rainfall and runoff patterns. Hydropower helps to improve air quality by making it possible to burn less coal, oil and gas—technologies that release carbon dioxide into the air. In addition, hydroelectric generation can be dispatched, meaning it can be turned on and off, as long as sufficient water is present. This allows TVA fossil and nuclear units to operate at maximum efficient capacity and minimizes the need to reduce their output to match power needs during hours of the day when demand for electricity is lower.

The operating cost of hydroelectric generation is also very low compared to most other generation sources. TVA has taken many steps to improve the operation of its hydroelectric plants in recent years. These include the implementation of an aggressive Reservoir Releases Improvement program in the early 1990s, which is continuing today. As part of this program, TVA installed equipment and made operational changes to improve the quality of the water as well as the associated fish and invertebrate populations in the tailwater river sections downstream of its dams. Additional operational changes were made in 2004 as a result of the Reservoir Operations Study.

Hydroelectric – New Generation

TVA included additional as-yet-unapproved modernization projects (a total of 90 MW by 2029) as a resource option for its IRP evaluation. TVA also included small- and low-head hydropower as an IRP resource option.

A Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) study (DOE 2006) estimated the amount of additional hydropower resources that are feasible for development within the TVA region. The EERE report estimates the annual average power available for development and, of that available amount, how much would be feasible to develop. Using average capacity factors, this total feasible hydropower capacity is estimated at 1770 MW. None of the feasible capacity is categorized as large power sources (greater than 60 MW). 70% of the feasible capacity was categorized as small hydro (less than 60 MW and greater than 2 MW), and 30% was low power resources (less than 2 MW). Low power resources include conventional technology, ultra low head and kinetic energy turbines, and micro-hydro power. TVA included up to 144 MW of small hydro by 2029 as a resource option evaluated in the IRP.

See Section 4.3.4 on energy storage for discussion of pumped-storage hydropower resource options.

4.3.3.2 Wind

Wind – Existing Facilities

TVA currently owns a 3-turbine, 2-MW wind farm. It has also entered into contracts with third party developers for the long-term purchase of wind power. TVA included the purchase of this wind power through PPAs as a resource option for its IRP evaluation. Depending on the wind resource option, 1330 to 2740 MW (which takes into account transmission delivery losses) of additional wind power will be added by 2029 in the IRP evaluation as purchased power. For reasons discussed below, TVA did not include the self-build options for acquiring additional wind power resources for the TVA generation portfolio.

In mid-2010, TVA began to receive power from the first of what will eventually be a contracted capacity addition (totaling 1380 MW) of wind power to its renewable portfolio through power purchase agreements that resulted from a request for proposals that were issued in December 2008. Iberdrola Renewables began supplying 300 MW from Streator-Cayuga Ridge wind farm in Livingston County, Illinois. Additional wind power agreements exist with Horizon Wind Energy LLC (115 MW starting fall 2010), CPV Renewable Energy Company (365 MW starting 2012), and Invenergy LLC (600 MW starting in 2012).

All new wind contracts were competitive with forecasted market electricity prices at the time those contracts were evaluated. All contracts are contingent on meeting applicable environmental requirements and obtaining firm transmission paths to TVA.

Wind – New Generation

TVA did not include the option of constructing its own wind power facilities in the TVA region, but instead favored the approach of procuring wind power resources through PPAs. As a federal agency, TVA cannot take advantage of the current investment incentives offered to wind power developers. TVA does not have in-house expertise and experience in building and operating wind facilities, and acquiring this expertise is not necessary because the wind industry already has the necessary capability to supply TVA's needs. Overall, the procurement of wind resources, whether in the TVA region or imported to the TVA region, through an RFP process ensures lower cost to TVA customers.

According to a Tennessee Wind Map and Resource Potential estimate from the DOE's Office of Energy Efficiency and Renewable Energy (DOE 2010), approximately 4,200 MW of wind power capacity based on a turbine hub height of 80 meters is available in the TVA service area at a gross capacity factor of 25%. Most current turbine installations have hub heights between 50-80 meters. However, 100-meter hub heights are technically feasible with current wind turbine technology, and taller turbines could help wind power become more economically feasible in low wind areas such as the TVA service area. It is estimated that approximately 57,000 MW of wind power capacity is available in the TVA service area at a turbine hub height of 100 meters.

Taking into account electrical losses, environmental factors and wake effects (of surrounding wind turbines), the net capacity factor for the TVA service area is projected to range from 20-22%, which is on the low end of the typical 20-40% range of net capacity factors for modern utility-scale wind power projects. Taller turbine hub heights do not increase the net capacity factor significantly. The advantages of wind power are no fuel costs, relatively simple design with short lead time for construction and operation, no emissions, and offsetting of greenhouse gases. Disadvantages include limited regional sites with no greater than class 3 wind; turbine siting resistance due to aesthetic, visual and potential noise concerns; and competition for "choice" sites with regional competitors. In addition, wind tends to require additional resources to be built, in the form of energy storage technologies or back up generation resources, in order to provide back-up balancing supply to address the intermittency of wind generation.

4.3.3.3 Solar

Solar – Existing Generation

TVA owns 15 photovoltaic installations with a combined capacity of about 400 kW. TVA also purchases power from photovoltaic installations through the Generation Partners program.

Solar – New Generation

TVA included the purchase of solar power through PPAs as a resource option in its IRP portfolio. TVA did not include the option of constructing its own solar facilities for the same reasons that the construction of wind power facilities was not included (see Section 4.3.3.2).

Generation from solar power is available in two main technologies: concentrating solar power (CSP), also known as solar thermal, and photovoltaic (PV).

1. CSP technologies (i.e., solar thermal plants using parabolic troughs, power tower, etc.) were not evaluated in detail as IRP resource options due to the low rate of delivery of solar radiation within the TVA territory. For example, direct solar radiation in Memphis is approximately 4.4 kilowatt-hour per square meter per day (kWh/m2/day) (NREL 2010), which is below the minimum level of 6.75 kWh/m2/day required for a viable CSP generating facility (Balir 2006).

2. A solar PV cell is made of semiconducting material so that when the sunlight strikes the cell the electrons flow through the material and produce electricity. Thus, there are no moving parts required to generate electricity. Solar PV can make use of both direct solar radiation and diffuse horizontal radiation, which is one reason PV is technically feasible in more areas of the United States than solar thermal technologies. The average solar radiation for PV technology was estimated from National Renewable Energy Laboratory's solar radiation map (NREL 2010) for the western portion of the TVA region to be 4.9 kWh/m2/day. The solar PV capacity factor in the western portion of the TVA service region is calculated at 17%, which is equivalent to approximately four hours of usable solar radiation available each day. TVA included the option of obtaining PPAs for up to 400 MW of solar PV facilities by 2029 as an IRP resource option.

4.3.3.4 Biomass

Biomass – Existing Generation

Biomass power plants use organic matter to generate electricity. It is one of the few renewable power options that can be operated at a relatively high capacity factor (85%) and is "dispatchable," meaning that its generation can be planned and scheduled much like a conventional fossil-fueled unit. TVA is currently performing biomass fuel availability surveys in the region, and a comprehensive study is underway to assess the feasibility of converting one or more coal-burning units to biomass fuel. In addition, TVA generates electricity by co-firing methane from a nearby sewage treatment plant at Allen Fossil Plant and by co-firing wood waste at Colbert Fossil Plant. TVA presently purchases about 91 MW of biomass-fueled generation. These purchases include 9.6 MW of landfill gas generation, 70 MW of wood waste generation and 11 MW of corn milling residue generation.

Biomass – New Generation

TVA included up to 500 MW of biomass generated PPAs and landfill gas generated PPAs as resource options to be evaluated in the IRP. TVA also included the conversion of existing coal-fired units to biomass-fired units and co-firing biomass with coal at existing coal-fired units as IRP resource options to be evaluated. Conversion of existing coal-fired units to biomass or co-firing with coal does not add capacity to these units. For reasons discussed below, TVA did not include the resource option of using municipal solid waste as a fuel.

Agricultural and forest resources provide the most prevalent form of biomass fuel available in the TVA region. These include agricultural "crop" residues (i.e., by-products of harvest), dedicated energy crops (e.g., switchgrass on Conservation Reserve Program [CRP] lands), forest residues (i.e., waste products from logging operations) and methane gas by-products from livestock manure. Biomass resources, such as primary milling residues (i.e., by-products of commercial mills), secondary milling residues (i.e., by-products of woodworking and furniture shops), urban wood residues (i.e., waste wood products from construction, demolition and residential), and methane gas by-products from landfills and wastewater treatment facilities are being considered but are not as prevalent in less densely populated regions such as the TVA service territory.

Stoker grate technology is well proven in the biomass power generation industry and is commercially available. Stoker grate technology is effective in burning solid fuels that contain fuel particles of sufficient size that they must rest on a grate to burn as well as finely sized particles. Solid fuel is introduced into the furnace using pneumatic or mechanical spreaders, which "stokes" (feeds) the furnace (EPRI 2009).

Fluidized bed combustion (FBC) systems have been commercially available for over 20 years in the United States and for longer abroad. Biomass fuels have been successfully fired on many of these units. FBC systems operate on the fluidization process, which begins with a bed of solid granular particles, such as sand or limestone, suspended by an upward flow of air or gas. Combustion temperature is lower than the conventional boiler, which reduces nitrogen oxide production (EPRI 2009). Typical stoker boiler or fluidized bed systems are about 50 MW and can be operated at a capacity factor of about 80%.

A form of small-scale base load power is landfill gas. The natural decay of biomass in landfills produces methane, which can be captured and used in generators for power production. This also reduces the release of methane into the atmosphere. Methane can also be produced from biomass through a process called anaerobic digestion as in wastewater treatment lagoons. Natural bacteria are used to decompose organic matter in the absence of oxygen, producing methane-rich biogas, which is used to produce electricity in a generator. The benefits of utilizing landfill gas are the conversion of waste materials into usable form of energy and the reduction of emissions of potent greenhouse gases. Disadvantages include the limited transmission line availability and uncertain quantity of gas from landfill, causing an uncertain plant lifetime. Because of the small scale, TVA included the landfill gas PPAs as a resource option in the IRP evaluation.

Municipal solid waste (MSW) contains organic materials that can be combusted to produce power. Availability is located in mostly urban centers where waste is collected and sorted to remove non-combustible materials. TVA considers this resource option to be limited due to low availability of waste materials and complexity and uncertainty of emissions. Therefore, TVA has not included fuel by MSW as a resource option in the IRP evaluation.

4.3.4 Energy Storage

An energy storage facility has the ability to store off-peak energy from renewable resources and low cost, off-peak energy from hydropower and thermal resources. This provides significant benefit during periods of low load, when many utilities struggle to meet their system minimum load due to the inability of on-line base load or intermediate resources to reduce generation. The energy stored is then used to provide generation during high peak demand periods. As an additional benefit, availability of an energy storage facility allows on-line resources to operate at a more efficient operating level throughout the day by reducing the range between minimum and peak load.

Energy Storage – Existing Generation

TVA operates one large energy storage facility, the 1615 MW Raccoon Mountain Pumped-Storage Plant. In pumped-hydro storage, water is pumped from a lower reservoir to the upper reservoir using off-peak power. During the generating cycle, water is discharged from the upper reservoir through the reversible pump/turbine-generators located in an underground powerhouse. Pumped-hydro storage facilities have relatively long storage times of 10-20 hours compared to other storage technologies. Thus, pumped-storage hydropower can provide intermediate power to the region. The emissions from a pumped-hydro plant are essentially zero. There are, however, emissions associated with the source of the power used during the pumping cycle.

Energy Storage – New Generation

Two pumped hydroelectric storage resource options at capacities of 850 and 960 MW are included in the IRP evaluation. In addition, a compressed air energy storage (CAES) option is further evaluated in this IRP. As discussed below, TVA did not further evaluate any electric battery storage options.

Limited sites can be considered for conventional pumped-hydro installations because of the required elevation difference between the two reservoirs; however, several sites have been identified in the TVA region. More detailed analyses of these sites, including consideration of site-specific impacts, would be conducted when TVA proposes such projects.

A compressed air energy storage (CAES) plant operates in two cycles. During periods of relatively low electricity demand when power generation costs are low and/or excess energy is supplied from renewable energy sources (e.g., wind), air can be compressed and stored in an underground reservoir. The equipment is analogous to the compressor used in a combustion turbine, and the process is similar to the pumping and storing of water at a higher elevation in pumped-hydro. Then, during periods of high electricity demand, the pressurized air from the underground reservoir is mixed with a fuel (natural gas), burned, and expanded through a high-pressure turbine to produce power. Thus, a CAES unit can provide peaking or intermediate power. As with pumped-hydro, there may be emissions associated with the source of power used during the pumping cycle. There will also be emissions from the combustion process during the generation cycle.

Based on extensive studies of underground storage in the oil and natural gas industry, several geologies appear to be suitable for air storage: salt domes; aquifers, including depleted natural gas fields; and hard rock. Some of these geologic formations are accessible from the TVA region. Located in Alabama, the McIntosh CAES plant is currently in operation in the U.S. with a nameplate capacity of 110 MW. The option under consideration in the IRP has an installed capacity of 330 MW.

Energy storage via batteries is still in the developmental phase at this time and therefore has high uncertainty and risk for utility scale power generation. In addition, the degree of development is not at a large enough size to support utility-scale power generation. Because of these reasons, TVA did not include electric battery storage in its IRP evaluation.

4.3.5 Energy Efficiency and Demand Response

TVA has an existing portfolio of programs focused on energy efficiency and demand response (EEDR) and has included additional EEDR programs in its IRP evaluation. Energy efficiency programs are designed to promote the use of less energy to provide the same level of energy service. Demand response programs are designed to temporarily reduce a customer's use of electricity, typically during peak periods when demand is highest.

TVA develops its EEDR programs in cooperation with the appropriate committees, staff and executives of the Tennessee Valley Public Power Association (TVPPA) and includes representatives of individual power distributors on the product development teams. The partnership with the power distributors and the TVPPA is critical to the collection of market research data, identification of product needs, development of program designs, market testing of products and the ultimate implementation of EEDR programs. Although many new programs are utilizing the turnkey approach through third-party vendors, the decision on implementation lies with the individual power distributors. Designing programs that clearly benefit all three parties—power distributors, end-use consumers, and TVA—has been and will continue to be the key element to successful implementation. Program benefit estimates include an evaluation of potential distributor participation.

The EEDR targets used in the IRP Planning scenarios reflect the benefit from programs that TVA can implement. They do not consider additional energy efficiencies that are gained from regulation (like CFL mandates) or state statutes (like building code changes) or consumer behavior changes from education. These external, non-TVA driven energy efficiency savings are partially reflected (though not captured separately) in the load/demand forecasts whereas, energy efficiency savings resulting from TVA actions are treated in the IRP as a supply "avoidance" option.

EEDR programs evaluated in the IRP do not include interruptible load contracts totaling about 680 MW of avoided capacity that TVA has with industrial customers to reduce the flow of energy to them during high demand periods. Expansion of these contracts was not reviewed in the planning process because TVA is focusing on the development of time of use pricing products whose anticipated effects are reflected in the load forecast and the amount that interruptible contracts, as currently formulated, might be increased is not significant.

TVA's approach is to ensures that energy efficiency and demand response programs move toward a self-sustaining future by:

- Stimulating and transforming the marketplace instead of "buying the market" with incentives.
- Supporting development of efficiency standards and regulations.
- Providing incentives for energy efficiency and demand reduction in conjunction with proper pricing signals.
- Enabling automatic metering and direct load control.
- Expanding and supporting cleaner end-use generation.

Energy Efficiency and Demand Response (EEDR) programs are targeted towards residential, commercial and industrial customers and offer potential ways to help TVA manage energy consumption and the growth in peak demand. Since the 1970s, TVA has had residential, commercial, and industrial programs to reduce peak demand and energy consumption. As currently implemented, TVA's EEDR portfolio focuses on reduction in peak demand and has an avoided peak capacity of about 250 MW.

TVA's experience to date is that successful energy efficiency programs are highly dependent on the end users' recognition of the cost effectiveness of efficiency. TVA recognizes the important role energy efficiency plays in shaping the load balance and is committed to building EEDR programs for their important resource potential. As part of the Integrated Resource Planning process, TVA has developed program initiatives to focus on reducing energy consumption as well as decreasing peak demand.

Accumulation of benefits from EEDR programs is dependent on factors such as the participation rate of the program, development of implementation infrastructure, and participant economics. Estimates of participation rates in the program designs by both power distributors and end-users are based on past program experience, market analysis, and financial assessment of incentives. Thirty-plus years of DSM program experience with power distributors have shown that no design receives universal acceptance; however, programs designed to provide benefits to TVA, power distributors and end-users will receive significant levels of adoption by power distributors if administrative burden can be minimized. No program design assumes full participation of all distributors.

Participation rates for end-users are based on experience with similar products, analysis of potential eligible consumers, market research on consumer interest, and analysis of participant economic drivers. Incentive rates are calculated to decrease any financial burden to an acceptable level commensurate with the savings to the participant. Focus groups and market research surveys are utilized to identify financial and other motivations to move potential program participants. All programs do not rely solely on cash incentives, but may include a mixture of needed services or information along with financial considerations such as incentives or loans. External economic conditions, however, can produce unanticipated variation in participation requiring mid-stream correction incentive levels, advertising or services provided.

Program infrastructure may include staffing by TVA or distributor, third-party resources, and technical support such as databases and websites. Program designs provide for slower adoption rates in the initial years of deployment to permit development of infrastructure and training of staff. In an effort to minimize administrative burden for both TVA and power distributors, designs frequently employ third-party contractors to supply support and prior expertise. Development of independent resources permits a firmer link between performance and cost without the additional burden of staff impacts associated with shifting priorities or significant program changes.

EEDR program designs also address operational risk through a variety of methods. All designs include estimates of measure life and degradation over time, as noted previously, in recognition of the fact that actions taken or equipment installed do not last forever and must be replaced over time. In addition, components of EEDR benefit calculations utilize conservative estimates of the various factors involved. An assessment of the risk associated with projections of benefits from EEDR programs by Huron Consulting judged the methodology used to produce low estimates of overall savings. The TVA supply planning process also includes hedging supply through the purchase of long-term power purchase options. The deployment of a wide variety of program options provides the ability to scale up the focus on one program or target market in response to lower than expected performance in another program.

Figures 4-1 and 4-2 show the benefit from EEDR options on avoided capacity and avoided generation through 2029 for each of the IRP strategies.

Figure 4-1 – Avoided Capacity of EEDR Options

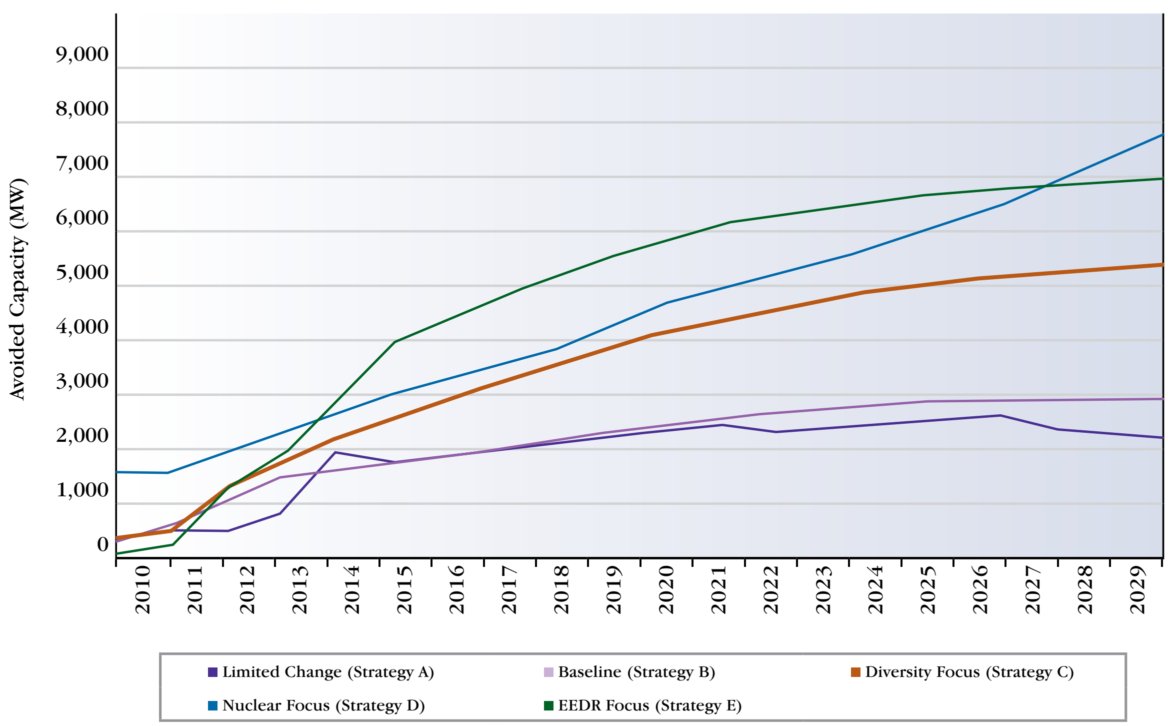
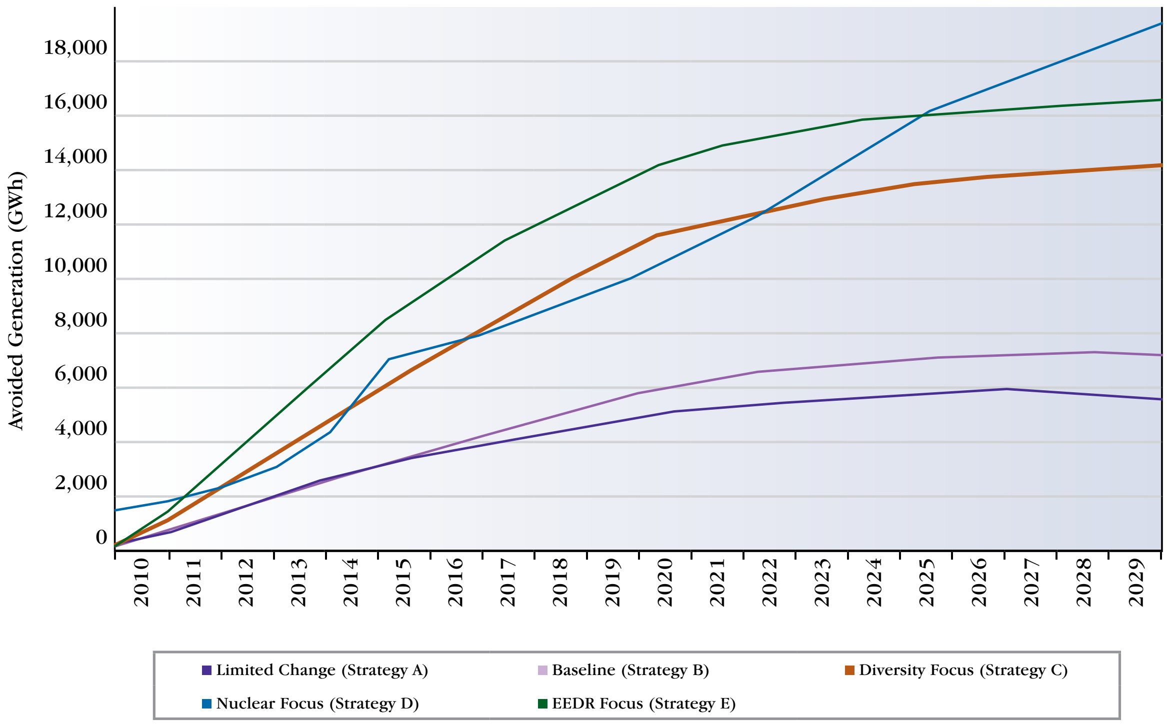


Figure 4-2 – Avoided Generation of EEDR Options



The EEDR options in Figures 4-1 and 4-2 include differing amounts of the following program elements:

- Residential programs for new site-built and manufactured homes, *energy right* home evaluations and in-home energy assessments, heat pump and high-efficiency air conditioning installation and maintenance, and weatherization assistance.
- Commercial and industrial programs providing technical assistance, efficiency advice, incentives, and audits for new and existing facilities.
- Demand response programs for interruptible loads, direct load control and conservation voltage regulation.

This IRP incorporates an EEDR program into the IRP Baseline case and all resource options considered that reflects the energy efficiency that can result from TVA's programmatic efforts. These reductions are in addition to those energy savings that are naturally occurring due to existing laws and policies and the independent programs of its distributors. The IRP Baseline strategy includes an EEDR program that reduces required energy and capacity needs by about 7,300 GWh and 2,900 MW, respectively, by 2029.

Currently available programs include the following:

4.3.5.1 Residential Energy Efficiency

In-Home Energy Evaluation Program – Tests for the new residential program, called the In-Home Energy Evaluation Program, began in 22 markets including Nashville, Chattanooga and the Tri-Cities area (Bristol, Johnson City, and Kingsport) in Tennessee as well as Hopkinsville, Kentucky, and Huntsville, Alabama. The program will offer comprehensive in-home energy audits as well as financing options and incentives to help homeowners who choose to make investments in significant energy efficiency improvements. The homeowner pays for the evaluation, but TVA rebates the evaluation cost to homeowners who have made at least $150 in improvements and had a post-installation inspection. The goal of this program is to educate and motivate the consumer to save energy through improving his or her home. This program was introduced in 2009 and will be available throughout the TVA area by October 2010.

New Homes Program – Provides incentives for builders to construct new homes with increased energy efficiency. Incentives range from $300 to $800 depending on the efficiency of the home. There are three levels of efficiency:

1. Homes built *energy right*® must meet a minimum rating in overall energy efficiency (at least 7% better than standard code requirements).
2. Homes built 15% better than standard qualify as *energy right* Platinum.
3. To qualify for the $800 incentive, *energy right* Platinum certified homes require additional testing at the expense of the builder or homeowner in addition to being 15% better than standard code requirements.

Do-It-Yourself Home Energy Evaluation – Homeowners complete a home energy survey, either online or on a paper form submitted to TVA. The homeowners then receive a personalized report that breaks down their annual and monthly energy usage by category and makes recommendations for increasing energy efficiency. Participants also receive a free energy efficiency kit that may include items such as compact fluorescent light bulbs and gaskets for wall outlets and light switches.

New Manufactured Homes Program – Provides incentives for manufacturers and dealers that install high-efficiency heat pumps in new manufactured homes. Qualifying heat pumps must have a seasonal energy efficiency ratio (SEER) of at least 13 to qualify for a $300/home incentive. TVA is also piloting an ENERGY STAR Manufactured Homes effort with the Manufactured Housing Research Alliance.

Heat Pump Program – TVA promotes the installation of high-efficiency heat pumps in homes and small businesses by providing low-interest, fixed-rate financing for up to 10 years through a third-party lender, with repayment through the consumer's electric bill. TVA has established a Quality Contractor Network of installers meeting high standards. Local distributors, who are reimbursed by TVA for inspection and loan processing/collection, arrange financing.

4.3.5.2 Commercial and Industrial Energy Efficiency

Commercial Efficiency Advice and Incentives Program – A new initiative targeting businesses and institutions that have 50 kW or greater peak demand that began testing in the Mississippi district and Nashville. This program will offer businesses an opportunity to receive an energy assessment of their facilities to help them identify energy-saving opportunities. Financial incentives of $200 per summer peak kW are also available for projects that help reduce power consumption during TVA's peak period. The goal of the program is to reduce the power demand during TVA's critical peak period.

Major Industrial Program – Targets very large industrial direct-served and distributor-served customers with contract demand greater than 5 MW and offers technical assistance and incentives for energy efficiency projects that lower their demand for power during peak usage periods on the TVA system. Approximately 250 large industrial customers throughout the TVA area are eligible to participate. Participants who implement qualified projects may be eligible for financial incentives of $100 per kW of load reduced during TVA's critical peak period. The goal of this program is to achieve 10% peak demand reduction at each participating facility by 2014.

4.3.5.3 Demand Response

Commercial and Industrial Demand Response – TVA provides incentives to businesses shifting energy-intensive operations from periods of high power demand to periods of lower demand. Participants must be able to achieve a demand response reduction of at least 100 kW and be available for dispatch up to 80 hours per year. Demand reduction events are dispatched and monitored with near-real-time software. Participating customers receive monthly capacity and energy payments based on their performance during demand reduction events.

Conservation Voltage Regulation Program – Uses conservation voltage regulation (CVR) by power distributors to achieve capacity and energy savings through operation of distribution feeders in the lower portion of the ANSI service voltage requirement range, either continuously or on a dispatch-basis.

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